ON THE NATURE OF VIBRATORY MOTIONS[1]

II.

Blackburn's Double Pendulum.

EXPERIMENT 7.—Let us return to our sand-pendulum. We have examined the vibrations of a single pendulum, let us now examine the vibrations of a double pendulum, giving two vibrations at once. The little copper ring *r*, in Fig. 7, on the cord of our pendulum, will slip up and down, and by moving it in either direction we can combine two pendulums in one. Slide it one quarter way up the cord, and the double cord will be drawn together below the ring. Now, if we pull the bob to the right or left, we can make it swing from the copper ring just as if this point were a new place of support for a new pendulum. As it swings, you observe that the two cords above the ring are at rest. But the upper pendulum can also be made to swing forward and backward, and then we shall have two pendulums combined. Let us try this and see what will be the result.

Just here we shall find it more convenient to use the metric measure, as it is much more simple and easy to

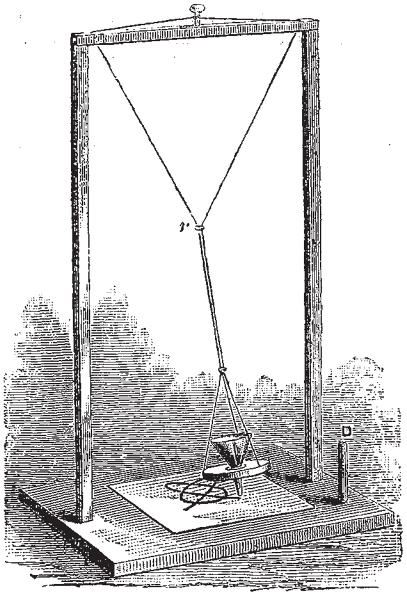

FIG. 7.

remember than the common measure of feet and inches. If you have no metric measure you had best buy one, or make one. Get a wooden rod just $39\frac{37}{100}$ inches long, and divide this length into 100 parts. To assist you in this you may remember that 1 inch is equal to $25\frac{4}{10}$ millimetres. Ten millimetres make a centimetre, and 100 centimetres make a metre.

Now slide the ring *r*, Fig. 7, up the cords till it is 25 centimetres from the middle of the thickness of the bob. Then make it exactly 100 centimetres from the under side of the cross-bar to the middle of the thickness of the bob, by turning the violin-key on the top of the apparatus.

At D, Fig. 7, is a small post. This post is set up anywhere on a line drawn from the centre of the platform, and making an angle of 45° with a line drawn from one upright to the other. Fasten a bit of thread to the string on the bob that is nearest to the post, and draw the bob toward the post and fasten it there. When the bob is perfectly still fill the funnel with sand, and then hold a lighted match under the thread. The thread will burn, and the bob will start off on its journey. Now, in place of swinging in a straight line, it follows a curve, and the sand traces this figure over and over.

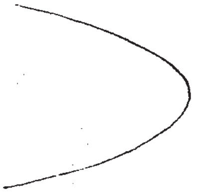

FIG. 8.

Here we have a most singular result, and we may well pause and study it out. You can readily see that we have here two pendulums. One-quarter of the pendulum swings from the copper ring, and, at the same time, the whole pendulum swings from the cross-bar. The bob cannot move in two directions at the same time, so it makes a compromise and follows a new path that is made up of the two directions.

The most important fact that has been discovered in relation to the movements of vibrating pendulums is that the times of their vibrations vary as the square roots of their lengths. The short pendulum above the ring is 25 centimetres long, or one-quarter of the length of the longer pendulum, and, according to this rule, it moves twice as fast. The two pendulums swing, one 25 centimetres and the other 100 centimetres long, yet one really moves twice as fast as the other. While the long pendulum is making one vibration the short one makes two. The times of their vibrations, therefore, stand as 1 is to 2, or, expressed in another way, 1 : 2.

Experiment 8.—Let us try other proportions and see what the double pendulum will trace. Suppose we wish one pendulum to make 2 vibrations while the other makes 3. Still keeping the middle of the bob at 100 centimetres from the cross-bar, let us see where the ring must be placed. The square of 2 is 4, and the square of 3 is 9. Hence the two pendulums of the double pendulum must have lengths as 4 is to 9. But the longer pendulum is always 1,000 millimetres. Hence the shorter pendulum will be found by the proportion 9 : 4 : : 1,000 : 444·4 millimetres. Therefore we must slide the ring up the cord till it is 444·4 millimetres above the middle of the thickness of the bob.

Fasten the bob to the post as before, fill it with sand, and burn the thread, and the swinging bob will make this singular figure (Fig. 9).

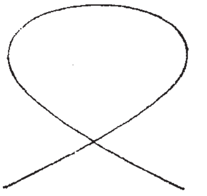

FIG. 9.

Experiment 9.—From these directions you can go on and try all the simple ratios, such as 3 : 4, 4 : 5, 5 : 6, 6 : 7, 7 : 8, and 8 : 9. In each case raise the two figures to their squares, then multiply the larger number by 1,000, and divide the product by the smaller number; the quotient will give you the length of the smaller pendulum in millimetres. Thus the length for rates of vibration, as 3 is to 4, is found as follows: $3 \times 3 = 9$, $4 \times 4 = 16$, and $\frac{9 \times 1{,}000}{16} = 562{\cdot}5$ millimetres.

The table (Fig. 10) gives, in the first and second columns, the rates of vibration, and in the third and

[1] From a forthcoming work on "Sound: a Series of Simple, Entertaining, and Inexpensive Experiments in the Phenomena of Sound, for the Use of Students of every Age." By Alfred Marshall Mayer, Professor of Physics in the Stevens Institute of Technology. Communicated by the Author. (Continued from p. 574.)

fourth columns the corresponding lengths of the longer and shorter pendulums. Opposite these lengths are the figures which these double pendulums trace. In the sixth column are the names of the musical intervals formed by two notes, which are made by numbers of sonorous vibrations, bearing to each other the ratios given in the first and second columns.

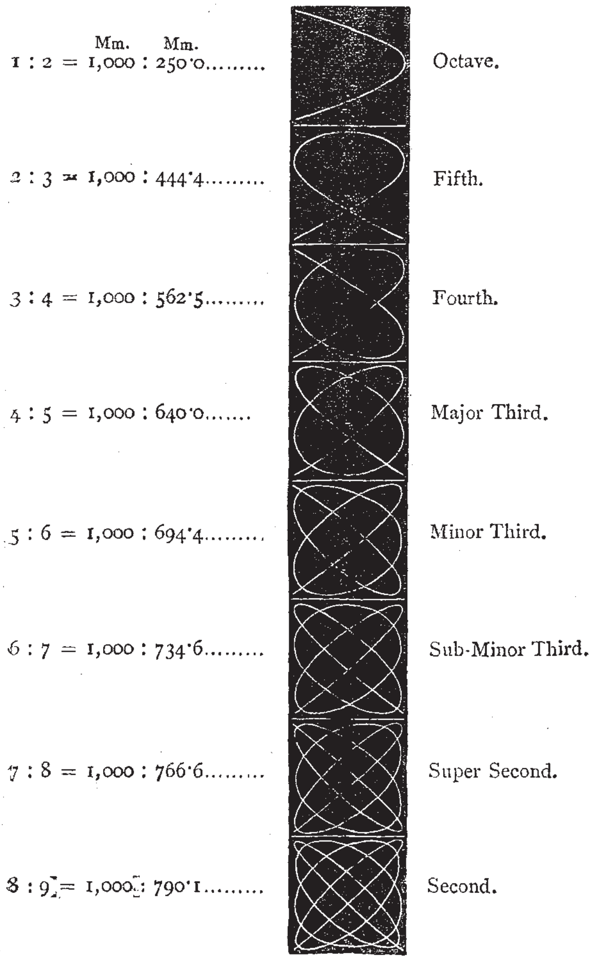

FIG. 10.

Prof. Kundt's Experiment, made with a Whistle and a Lamp Chimney, showing that, as in Wind Instruments, a vibrating Column of Air may originate Sonorous Vibrations.

Experiment 10.—The chimneys of student-lamps have a fashion of breaking just at the thin, narrow part near the bottom. Such a broken chimney is very useful in our experiments. At A, in Fig. 11, is such a broken chimney, closed at the broken end with wax. A cork is fitted to the other end of the chimney, and has a hole bored through its centre. In this hole is inserted part of a common wooden whistle. At B is an exact representation of such a whistle, and the cross-line at C shows where it is to be cut in two. Only the upper part is used, and this is tightly fitted into the cork.

Inside the tube is a small quantity of very fine precipitated silica, probably the lightest powder known. Hold the tube in a horizontal position and blow the whistle. The silica powder springs up into groups of thin vertical plates, separated by spots of powder at rest, as in the figure. This is a very beautiful and striking experiment.

Experiment 11.—The following experiment shows that the sound is caused by the vibrations of the column of air in the tube and whistle, and not by the vibrations of these solid bodies. Grasp the tube and whistle tightly in the hands. These bodies are thus prevented from vibrating, yet the sound remains the same.

The breath driven through the mouth of the whistle strikes on the sharp edge of the opening at the side of the whistle, and sets up a flutter or vibration of air. The air within the glass tube now takes part in the vibrations, the light silica powder vibrates with it, and makes the vibrations visible.

To exhibit this experiment before a number of people, lay the tube carefully on the water-lantern before the heliostat, and throw a projection of the tube and the powder on the screen. When the whistle is sounded, all in the room can see the fine powder leaping up in the tube into thin, upright plates.

Experiment 12.—Mr. Geyer has made the following

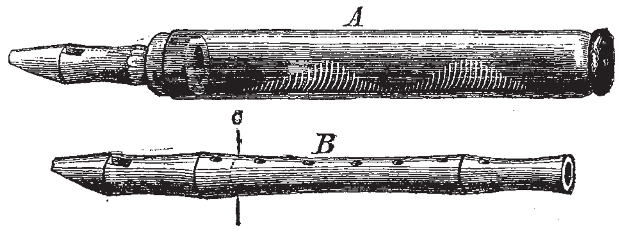

FIG. 11.

pleasing modification of this experiment:—Take a glass tube about 2 feet (61 centimetres) long and ¾ inch (19 millimetres) diameter. One end of this tube is stopped with a cork; then some silica is poured into it. The other end is placed in the mouth. Singing into the tube, a note is soon struck which causes the silica to raise itself in groups of vertical plates, separated by places where the powder is at rest, the number of these groups and their positions in the tube changing with the note sung.

We have now seen how solids, like steel or brass, may vibrate and give a sound. We have heard a musical sound from vibrating water, and these last experiments prove that a gas, like air, may also vibrate and give a sound. In the next chapter you will find experiments which show how these vibrations move through solids, through liquids, and through the air.

On the Interference of Sonorous Vibrations and on the Beats of Sound.

Experiment 13.—Cut out two small triangles of copper foil or tinsel, of the same size, and with wax fasten one on the end of each of the prongs of a tuning-fork. Put the fork in the wooden block and set up the guide. Prepare a strip of smoked glass, and then make the fork vibrate and slide the glass under it, and get two traces, one from each prong.

Holding the glass up to the light you will see the double trace, as shown in Fig. 12. You observe that the

FIG. 12.

wavy lines move apart and then draw together. This shows us that the two prongs, in vibrating, do not move in the same direction at the same time, but always in opposite directions. They swing toward each other, then away from each other.

Experiment 14.—What is the effect of this movement

of the prongs of the fork on the air? A simple experiment will answer this question.

Place three lighted candles on the table at A, B, and C (Fig. 13). Hold the hands upright, with the space between the palms opposite A, while the backs of the hands face the candles B and C. Now move the hands near each other, then separate them, and make these motions steadily and not too quickly. You thus repeat the motions of the prongs of the fork. While vibrating the hands observe attentively the flames of the candles. When the hands are coming nearer each other, the air is

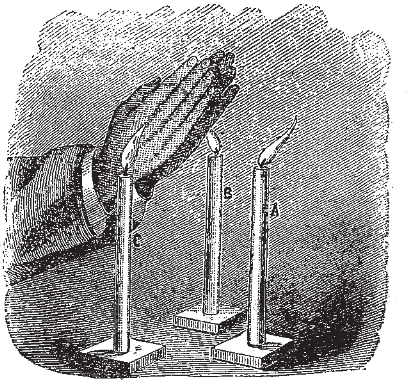

Fig. 13.

forced out from between them, and a puff of air is driven against the flame A, as is shown by its bending away from the hands. But, during the above movement, the backs of the hands have drawn the flame toward them, as shown in Fig. 13. When the hands are separating, the air rushes in between them, and the flame A is drawn toward the hands by this motion of the air, while at the same time the flames at B and C are driven away from the backs of the hands. From this experiment it is seen that the space between the prongs and the faces of the prongs

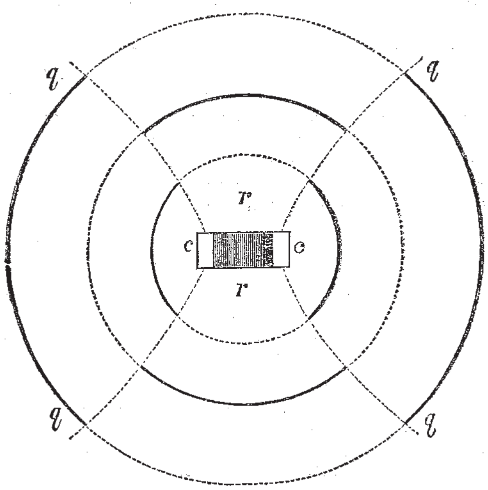

Fig. 14.

of a fork are, at the same instant, always acting oppositely on the air.

This will be made clearer by the study of the diagram, Fig. 14.

This figure supposes the student looking down on the tops of the prongs of the fork. Imagine the prongs swinging away from each other in their vibration. Then the action of the faces *c* and *c* on the air is to condense it, and this condensation tends to spread all around the fork. But, by the same movement, the space *r r* between the prongs is enlarged, and hence a rarefaction is made there. This rarefaction also spreads all around the fork. But, as the condensations produced at *c* and *c* and the rarefaction at *r* and *r* spread with the same velocity, it follows that they must meet along the dotted lines *q*, *q*, *q*, *q*, drawn from the edges of the fork outwards. The black ¼-circle lines around the fork in Fig. 14 represent the middle of the condensed shells of air, while the dotted ¼-circle lines stand for the middle of the rarefied shells of air.

Now what must happen along these dotted lines, or, rather, surfaces? Evidently there is a struggle here between the condensations and the rarefactions. The former tend to make the molecules of air go nearer together, the latter try to separate them; but, as these actions are equal, and as the air is pulled in opposite directions at the same time, it remains at rest—does not vibrate. Therefore, along the surfaces *q*, *q*, *q*, *q*, there is silence. When the prongs vibrate toward each other they make the reverse actions on the air; that is, rarefactions are now sent out from *c* and *c*, while condensations are sent from *r* and *r*, but the same effect of silence along *q*, *q*, *q*, *q* is produced.

Experiment 15.—That this is so is readily proved by the following simple experiment:—Vibrate the fork and hold it upright near the ear. Now slowly turn it round. During one revolution of the fork on its foot you will perceive that the sound goes through four changes. Four times it was loud, and four times it was almost, if not quite gone. Twirl the fork before the ear of a companion; he will tell you when it makes the loudest sound and when it becomes silent. You will find that when it is loudest the faces *c*, *c* of the prongs, or the spaces *r*, *r* between them, are facing his ear; and when he tells you that there is silence you will find that the edges of the fork, that is, the planes *q*, *q*, *q*, *q*, are toward his ear.

(*To be continued.*)

ON AN ASCENT OF MOUNT HEKLA, AND ON THE ERUPTION OF FEBRUARY 27, 1878

On February 27 last severe earthquakes were felt throughout the south-west portion of Iceland, particularly in the districts of Land, Rangarollir, Hreppa, and Fljotschlith, which are situated immediately to the south and south-west of Mount Hekla. Between 8 and 9 P.M. an intense illumination of the sky, at first believed to be actual fire, was seen to the south-east. This was found to be due to the reflection by clouds of the light emitted by molten lava within a subsidiary crater, or *bocca del fuoco*, as the Italians would call it, of Hekla. On the following day dense columns of smoke ascended from the crater, and quantities of volcanic ashes fell in the districts of Hreppa and Biskupstundur. The light was seen at Reykjavik, nearly seventy miles distant, and there appeared to be two vents of fire.

One month after the eruption Prof. Tómas Hallgrimson visited the district and endeavoured to discover the exact position of the new crater. He found it in the Raúdaskal Valley, about four miles to the north-east of Hekla, and in connection with one of its outlying spurs. The chief crater was observed to be near the northern base of Krakatinkr, and a good deal of new lava was heaped around it. Herr Nielsens, a merchant of Eyrabakki, on the southern coast of Iceland, visited the scene of the eruption about the same time, and by ascending Krakatinkr he was able to look down into the new crater. He also determined its position, and traced the course of the new lava streams. The map which is here reproduced (for which I am indebted to Sjera Gudmundr Jonsson, the priest of Stóruvellir, a hamlet near to Hekla) is a copy of Nielsens' sketch made on the spot.

Upwards of a month ago (August 21) I visited the scene